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PERCEPTION OF DISTANCE

IN an interesting article in No. 20 of this JOURNAL, Dr. Holt has reviewed three recent papers of von Rohr, Koehler and Wandersleb, on the subject of a new instrument constructed by the famous firm of Carl Zeiss in Jena. The apparatus is designed to produce plastic views of any photographic picture in monocular vision, and is called the verant, as it produces the true natural impression of the photographed objects. Dr. Holt's review was based on the three papers, while no copy of the instrument itself had then crossed the ocean. For a few days, however, the verant itself has been in my hands, and as it is, so far, the only one in this country, it may be in order to give an account of my first observations, as the idea of a stereoscope for one eye must naturally awaken the interest of the psychologist. The three papers mentioned approach the problem, not with the interest of a psychologist, but with that of the photographer and optician.

The instrument fulfills that which is promised in the more conservative statements of those papers. My eyes are strongly myopic. I am accustomed to wearing strong eye-glasses which correct my short-sightedness entirely. The prescription for the instrument is that myopic eyes should use it together with their normal eye-glasses. If I do so, the effect is very satisfactory. If I take, for instance, a small landscape picture of 9 × 12 cm. in size, taken with a kodak camera in which the distance of the plate from the lens is 15 cm., and look at it, as most convenient for my eye with correcting glasses, at a distance of 30 cm., I have the impression of a flat picture. If I close one eye and put the verant lens before the open eye and look now at my kodak picture, I can not get a distinct image at all at a distance of 30 cm., but must bring it as near as 15 cm. to get a sharp view, and as soon as I do so, the picture at once suggests a plastic interpretation. Yes, it can not be denied that the solidity of the objects in the landscape appears somewhat more natural than the well-known view in stereoscopic pictures where the impression is too easily one of a little stage in which one piece of scenery is set, without transition, behind the other. Everybody who inspects the photograph in this way seems to feel the same surprise; and yet I must confess that the only surprising fact to me is the discovery that this is new to all to whom I gave the instrument for inspection, and not least to those who are myopic like myself. We short-sighted persons can have exactly the same effect which the verant, together with biconcave eye-glasses, gives to our eyes as soon as we take off both the eye-glasses and the verant, and it seems almost inexplicable that every myopic person has not found this out for himself. For years I have been in the habit, if I want to enjoy a photograph, of taking off my eye-glasses, closing one eye, and bringing the photograph so near to the pupil that the angle under which I see the picture corresponds to the angle under which the view has been taken by the photographer. Not only the distant landscape, but every portrait assumes then at once a beautiful plasticity which far surpasses the effect of the stereoscope. The nearness of the object allows the restitution of the natural perspective, and all the motives of experience can thus cooperate to interpret the picture as the view of an object in three dimensions. As soon as the photograph is held at double the distance, the perspective is falsified, the plastic interpretation is inhibited, and this inhibition reaches, of course, its climax as soon as the photograph is looked at with both eyes, as the identical impression of both retinæ totally excludes a three-dimensional perception.

This inborn gift of the myopic eye is furnished by the verant to the normal eye, which is unable to see a picture as near as 15 cm. or less. The verant makes the eye short-sighted. It is a magnifying glass, which makes it easy for every normal eye to see a photograph at a distance of from 9 to 15 cm., and thus to reproduce, without any overstrain of accommodation, the angle of vision which belongs to the objects in nature. The lenses to be used have had to be calculated carefully. A much larger field of vision was needed than the usual magnifying glasses offer, and care had to be taken that the chief rays which pass through the magnifying glass should reach the fovea at every position of the eyeball when the eye is moving over the whole field. All this has been most successfully effected, as was to be expected of those optical masters whose recent improvements of microscope technique and whose new telestereometrical instruments deserve the highest credit. The large public, suffering from the defects of its virtues, deprived, that is, of the privilege of a natural magnifying glass on account of normal eyesight, will of course gladly make use of this system of lenses. But psychologically the apparatus does not offer anything new. If not every myopic person, then at least every myopic psychologist must have enjoyed these experiences before.

The defenders of the verant have made, however, a further statement which seems to involve in a still higher degree the interest of the psychologist. Dr. von Rohr, for instance, says in his paper, reprinted from the *Photographic Journal:* "Summing up, we come to the following conclusions: supposing a verant lens of the focal length of the camera objective, a normal eye will obtain, through the verant, as far as perspective and accommodation are concerned, the same impression it would obtain from the natural landscape when brought to the place of the entrance pupil of the camera lens. And if color is neglected the impression caused by the photograph will exactly correspond with that exercised by the natural objects. This necessarily affects our apprehension of relief, and our estimation of distance must correspond with the conclusions we should derive from monocular inspection of the objects themselves." In the same way, the other authors take for granted that perspective, accommodation and color are the only factors which can possibly influence our monocular perception of distance, and that abstracting from color, and the strain of accommodation being excluded, a picture seen under the angle under which it has been photographed must give exactly the impression of real nature. That is, we must have the feeling not only that there is some relative depth in the parts of the photograph which we see a few centimeters from our eyes, but that we are looking into the real landscape seen from the standpoint of the camera's lens.

This effect would not only be psychologically interesting, but it would be also of practical importance. It is well known, for instance, that the very desirable introduction of the stereoscope into the schoolroom has so far suffered from the undeniable fact that the stereoscopic impression is not at all that of the real landscape but merely that of a very small plastic model of it, which gives after a short time the fatiguing feeling of dealing with small toys and not with reality. Now if the verant really succeeded, through giving the right perspective and by avoiding strained accommodation, in giving the impression of far distance, this practical difficulty would be solved. But it is in this point that I think that the promises are not conservative; that we have been made to expect more than the apparatus offers. The perspective is correct, accommodation is not involved, and yet I do not see anything but a picture which is a few centimeters from my eye and which for immediate perception is absolutely different from a view into the real landscape. It appears exactly as it appears to my myopic eye without any glass. There, too, the perspective is correct, and the lens adjusted to its normal distance without accommodation, and yet there is no suggestion of reality, merely a suggestion of a small plastic model. Of course in the case of the verant, as in the case of the stereoscope, suggestible subjects can be easily brought to an affirmation of the question whether they see in the apparatus the same which they would see in real nature. The unusual and unexpected plastic character of the impression is then unwittingly substituted for the feeling of natural distance. But whoever is able to separate seeing in three dimensions from seeing in natural distance can not doubt that in both cases alike we reach the first end, the plastic interpretation, but are just as far removed from the other, the feeling of natural distance, as in the ordinary vision of pictures. The new instrument is thus in no way a real 'verant.'

The question arises, Why is that so? If I bring my landscape picture on a transparent glass plate into such a distance from my one eye that every point of this transparent photograph covers for my resting eye exactly the corresponding point of the real landscape and yet accommodation is excluded, as, for instance, in the case of the short-sighted eye, or in the case of the normal eye with the verant lenses, then we have exactly the retinal images of the real view of nature and the same repose of the lens. Why are we, nevertheless, absolutely unable to substitute the near object for the far one? This problem exists in spite of all the theoretical assurances that the one ought to appear exactly like the other, and I think that it is not impossible to furnish an answer to it.

If I am not mistaken, there is one point of difference between seeing the mere picture and seeing the far landscape, which has been neglected in the usual discussions. Every one knows, of course, that we see the picture and the landscape normally with the help of eye movements. The eye moves from point to point; but psychologists have neglected the consideration that the relation between eye movement and retinal image must be quite a different one for the landscape and for its photograph. Let us consider the simplest possible case, the case of the myopic eye without any lenses whatever, and without any need of accommodation for a picture as near to the eye as 10 cm. If I take a small landscape picture made with a camera whose distance from lens to plate is 10 cm., I have a splendid plastic view if I see it at a distance of about 10 cm. from my eye. I have before me just such a picture in which two mountain peaks are, in the photograph, 1 cm. distant from each other. If I now have my little picture at the distance of 10 cm. from the eye, these two mountain tops correspond in their distance of 1 cm. exactly to the retinal image which the two real mountains, which are ten miles away and one mile distant from each other, produce in my retina. The retinal image of the two mountain peaks in the photograph is thus for my resting eye indeed identical with that of real nature. Does that mean that I have to make the same eye movement to go from the left to the right mountain in the landscape as in the picture? Of course, that would be so, the movement would be just as identical as the retinal images if the nodal point of the light rays were identical with the rotation point of the eyeball. But everybody knows that this is not at all the case. The light rays cross in the lens. The angle of vision, and thus the size of the retinal image, are thus dependent upon the distance of the lens from the retina. But the movement of the eye is related to a rotation-point which lies about 13 mm. behind the cornea, roughly speaking 1 cm. behind the nodal point of the rays. This additional centimeter plays, of course, no rôle whatever, if I look at my mountains in the real landscape; following with my eyeball from the fixation-point of the left mountain to the fixation-point of the right mountain, I make a movement whose angle can be declared identical with the angle under which I saw the two mountains with the resting eye in the first position. This angle of vision was determined by the distance of the nodal point, which was in our case ten miles, while the angle of eye movement was determined by the distance of the rotation-point, which would be ten miles plus one centimeter, and there is of course no possible difference for practical discrimination between these two distances.

But the situation is completely changed if I turn to my little picture 10 cm. distant from my eye. The angle under which I see my two peaks is, of course, again the same under which I saw them in the real landscape. It is determined by the distance of the picture from the nodal point, which is in this case 10 cm. But the angle of the eye movement necessary to fixate first the left and then the right peak is now a much smaller one because it is again determined by the distance from the rotation-point, and that is in this case 10 cm. plus 1 cm. With this short distance of the picture from the eye this one additional centimeter is not at all the negligible quantity which it was in addition to ten miles in the landscape. For the two real mountains the angle of the eye movement had a tangent of one tenth; for the photograph mountains, in spite of their equal size of retinal image, the angle of necessary movement would of course have a tangent of one eleventh. Roughly speaking, we could say that the photograph, in order to produce the same eye movement which the mountains in the landscape excited, would need a pictorial distance between the two photograph mountains of 11 mm. instead of 10 mm. Of course if the distance in the picture were made 11 mm. instead of 10, it would not cover any more the mountains of the landscape. The retinal image would thus be relatively too large and would not give us any longer the true landscape. On the other hand, if we tried to correct it by bringing the picture one centimeter nearer to the eye, then of course every retinal image would be enlarged by that necessary tenth, and yet there would be no help for the situation, as now again the eye movement demanded by the retinal image would be relatively increased too.

We can put it in this way: *my real landscape demands a relation between retinal image and movement which my picture can not produce under any circumstances whatever.* That which would be needed to imitate the relations would be realized only if I had my retinal images from the picture at a distance of 10 cm., and at the same time the movements belonging to the same picture seen at a distance of 9 cm. That is of course unrealizable. We can not see a picture without having our movements constantly controlled by the size of the real retinal images, as it is necessary that the distance seen in indirect vision is the distance covered by the fixation-point during the eye movement. That demands, as we have seen, a different relation between retinal image and eye movement for near and far, and no verant and no stereoscope can eliminate this factor. If a 10-mm. object in the photograph demands an 11-mm. movement to give the impression of real natural distance, then we have a condition which can not be fulfilled.

If we remember how extremely delicate is our normal sensitiveness for retinal distances and how the newer studies in stereoscopic vision have demonstrated an unsuspected delicacy of adjustment between retinal images and motor responses, it is evident that this so far always neglected relation must be an extremely important one. If we have one adjustment of central reaction in which a certain eye movement corresponds to retinal images of one size, and another adjustment in which the same movements correspond to retinal images which are ten per cent. larger, we can really not expect our judgment of distance to neglect the difference between these two systems of relations. Of course they represent two extreme cases. Every distance beyond 10 cm. demands its special adjustment up to the point where the distance becomes too large to be influenced by the distance from the nodal point to the rotation-point. We must thus presuppose a sliding scale of ever new adjustments for the different distances at which we see any object, and we have, in this relation, probably not the least important factor in the judgment of the third dimension for relatively near objects, and probably even more important than the irradiation circles which control the accommodation, as these circles must be the same for objects which lie before and behind the fixation-point. Of course the whole system of our localizing reactions becomes through these considerations more complex by far than the schematizations of the text-books propose. But physiological optics has shown at every point in its development that mere simplification has not always meant a deeper insight into the real relations.

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NOTE ON THE PHYSICAL WORLD-ORDER.[1] I

IT is a matter of common experience that we know something of the meaning of the term *body* and of the distribution of *bodies in space and time* before we are acquainted with those physical laws which, where they are known, enable us to describe bodies in new ways and to arrange them in that system which we call the physical world.

The task of discovering these laws, of effecting these descriptions, of constructing this system, belongs to a group of sciences, which, though differing *inter se,* we are accustomed to include under the single name of *physical science.* I say we are accustomed to refer to a single physical science; I mean we constantly hear such questions as these: What is the *physical basis* of life? How far are differences of civilization due to *physical,* how far to economic, etc., causes? These and similar questions lead us to contrast a science of physical causes with such sciences as biology, psychology and sociology. But just what sciences are included under the head of the physical, and on what ground they are included is by no means an easy matter to determine. Perhaps all would admit to this class the sciences of physics and chemistry; some, with Helmholtz, would include geometry; others, with the 'mechanists,' would include biology. But even if we confine ourselves to general physics and chemistry, there are still to be noted wide differences in method. Between mechanics, say, and chemistry, these differences are of sufficient importance to make the problem of finding a common nature in the two branches of science an extremely difficult one.

Nevertheless, I think we can frame a definition which, if applied to the sciences actually known, would bring into one class those which are usually included under the head of physical science, and explain the uncertainty in which we remain concerning others.

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